*IOSR Journal of Business and Management (IOSR-JBM)*
*e-ISSN: 2278-487X, p-ISSN: 2319-7668. Volume 24, Issue 3. Ser. II (March. 2022), PP 31-39*
*www.iosrjournals.org*

# Road Maintenance Strategies and Road Pavement Performance Case Study of Developing Countries in Africa

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***Abstract***
*One of the critical key challenges in road pavement management failure is due to inadequate road maintenance interventions. Roads like any other structures require constant, timely and planned maintenance interventions to preserve its life and functionality. This study considered various maintenance strategies which included routine, periodic, performance based and emergency maintenance strategies and how they affect pavement performance. Based on these four maintenance scenarios which considered African developing countries due to its historical and inadequate road maintenance financing, the study used various pavement condition inspection survey reports to establish that poor, untimely, unplanned maintenance strategy greatly affected road performance. The result showed that these led to pavement failure, safety, environmental and increased cost of maintenance. The results showed a strong correlation factor of R-squared above 0.75. The study was based on three theories, namely project management competence theory, theory of constraint, and programme theory, all of which provided the framework of the study. The study targeted the following subjects: completed road projects, road construction agencies, donor agencies and road users. The study targeted a total population of 54 developing countries in Africa. The study used a descriptive research design. The study established that road construction agencies and relevant line ministries should ensure that proper maintenance planning is undertaken and incorporated in the life cycle road management for prolonged road life and ensure quality of road performance. This should be done with proper and timely data collection. Even when the roads are under performance based contract maintenance, road condition data analysis should form the basis of any road maintenance strategy.*

***Key Words**: Performance based contract, periodic maintenance routine maintenance, emergency maintenance, road performance*

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Date of Submission: 28-02-2022 Date of Acceptance: 10-03-2022

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## I. Introduction

### 1.1 Background of the study

Roads are the major asset of any country and to conserve them maintenance is essential. The delay of timely and planned maintenance works can lead to road collapse coupled with expensive rehabilitation reconstruction within its design life. The maintenance practice of the road predominantly based on the process where several maintenance activities like routine, periodic, emergency and performance based maintenance are well planned and carried out (Mulmi 2016).

Pavement deterioration is the process by which distress develop in pavement under the combined effects of traffic loading and environmental conditions. Road failure affects safety and performance quality of the road (Magdi M, 2017).

Maintenance includes all activities needed to keep a country's road network operating indefinitely. The measurement of quality in an integrated form is necessary to evaluate the performance of any project. A road construction project goes through various stages of lifecycle such as concept, design, construction, conformance and performance. Improvement in the quality performance of construction projects is linked with quality management in the road project life cycle (Mallawaarachchi and Senaratne, 2015).

Similar to time and cost, performance is an important function in road infrastructure developments; it is a key factor in assessing how well a road pavement will enact under traffic loading and when exposed to environment. Furthermore, it gives a tool to the clients and construction professionals to ensure that the desired results are obtained to produce high quality and long life roads. In roadway construction projects, the ultimate goal of an owner is to construct a road that will have high serviceability and durability under the local climatic conditions and traffic to which the road pavement will be exposed during its service life. A road pavement performance is a function of the road's quality which is influenced by various factors such as pavement's structural design, construction materials and the construction process by which these materials are built into pavement. Depending upon the above mentioned factors, the pavement deteriorates with the passage of time and the rate of deterioration varies widely (Ebrahim Abu et al., 2016).

Many roads in some developing countries across the globe have inadequate drainage systems, in which distress often starts from cracks and potholes on the road pavement either at the edges or along a road. Although many roads are in poor conditions due to various reasons, poor drainage becomes the most dominant reason.

While the importance of the provision of infrastructure to support socio-economic growth has to date been well recognized within government, the potential of infrastructure maintenance as a powerful tool of economic growth and service delivery needs to come more to the fore. Investing in infrastructure operation and maintenance offers outstanding opportunities for economic stimulation: jobs are created, capital expenditure goes further, and sustainable delivery can be achieved, while political imperatives and community aspirations can be met.

Infrastructure maintenance must be regarded as a strategic tool to promote improved service delivery, unlock funding, extend infrastructure to historically disadvantaged communities, and to support the nation's economy. Maintenance of existing infrastructure should not be seen as of secondary importance to the apparently more attractive prospect of new infrastructure.

The road maintenance optimization can be achieved using knowledge-based strategic planning systems. The collection and analysis of necessary data help design different road maintenance long-term strategies and the output results help select priorities for road maintenance. Optimal road maintenance strategy is the way to keep a fairly performing road network with available funds and reduced road user costs (Virgaudas 2020).

## 1.2 Statement of the Problem

In 2019 the total population of Africa was 1.34 billion (UN estimate) and the total Gross Domestic Product (GDP) was $ 2.6 trillion (2019), resulting in a Gross National Per Capita (GNP) of $ 1,970. Figures in excess of $226 billion are being spent on infrastructure development annually. This includes $153 million on the development of 210kms of road and $751 million for the development of the Kenya-Tanzania Highway. Despite this huge investment, over the past two decades an estimated $45 billion worth of road infrastructure has been lost owing to inadequate maintenance in the eighty-five developing countries reviewed in this policies study. This loss could have been averted with preventive maintenance costing less than $12 billion. (WB). Costs of Road Maintenance and Improvement Works vary from less than $30,000 a kilometer for unpaved roads to more than $200,000 a kilometer for Routine maintenance. The costs for maintaining both paved and unpaved roads rise steeply as a pavement condition deteriorates from fair to poor.

Many developing countries invest approximately 12% ($954m) of its planned capital expenditure for the year to road construction and rehabilitation, the reality is that there is minimal research study done to investigate why these projects fail in regard to quality performance. Besides lack of value for moneyif roads are implemented and poorly maintained, nonetheless, they can aggravate serious environmental impacts, cost overruns and corruption, while generating intense political and social conflict along with scarce economic benefit (Alamgir et al., 2019).Roads in African countries are characterized by failure of all kinds like surface deformation, cracks, disintegration, surface defects etc. and there is not just one reason for each type of failure. Many roads in developing countries collapse and fail before their design life because of failure, delays or improper maintenance strategy. Unless road maintenance strategies are well planned and undertaken at the right time, then road performance will still remain a big challenge among developing countries in Africa.

It is against this background that this research study seeks to establish the urgent need to deploy appropriate maintenance strategies among African countries to advice the donors, government, road agencies and other key stakeholders on the need to strengthen and support road maintenance strategies for improved road quality performance among developing countries in Africa.

## 1.3 Objectivesof the Study

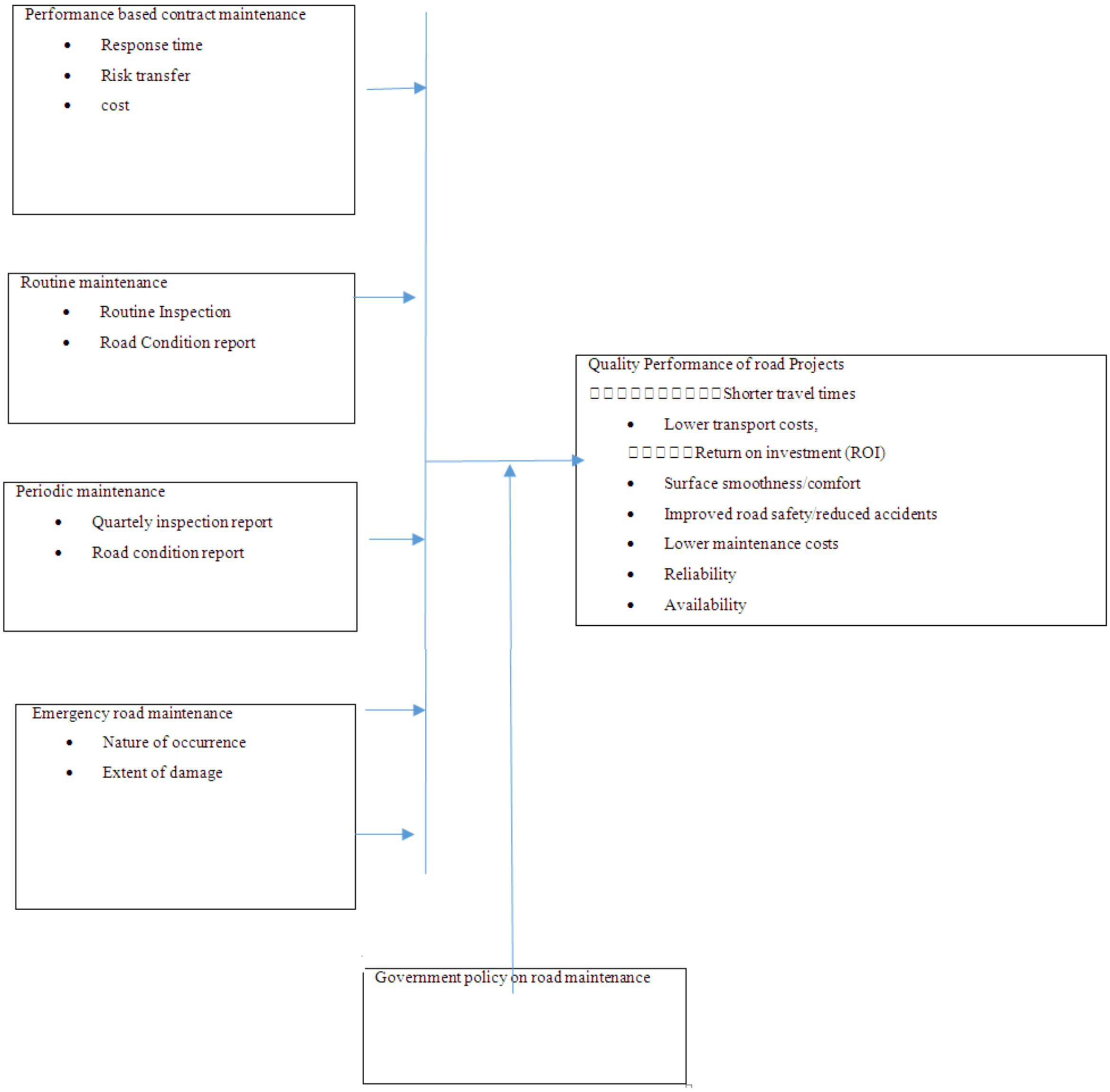
The study will guided by the following objectives, identify the types and level of pavement distress in developing countries assess the relationship between Road Performance based maintenance and road performance, identify the relationship of road routine maintenance and road quality performance in developing countriesstablish any significant effect of periodic maintenance and Road quality performance in developing countries identify when the road requires reconstruction for quality performance assess the moderating role of Government policy and regulation of the road construction sector on the relationship between maintenance strategies and road quality.

## 2.1 Theoretical Framework

In the study's approach to establish the relationship between the independent and dependent variables, the study is supported by the following theories; theory of project management competency has been applied in the current body of literature to demonstrate how competencies of project managers enhance project performance. Programme theoryis to ascertain the theoretical sensibility of the programme. A program theory consists of a set of statements that describe a particular program, explain why, how, and under what conditions the program effects occur, predict the outcomes of the program, and specify the requirements necessary to bring about the desired program effects A program theory provides a basis for evaluating relatively uncontrolled programs. Specifying a program theory to planners, staff members, people responsible for obtaining funding, and evaluators will assist them to carry out their duties while explaining how funding is being utilized. Theory of constraintsays there is always at least one constraint, and the theory of constraints uses what is called a focusing process to identify that constraint, and then restructures to address it. The theory of constraints works to find that link and lessen its vulnerability. That applies to processes, organizations, individual team members, whatever or whoever is a risk to the successful completion of the project.

## 2.2 Conceptual Framework

The conceptual framework for study is presented by in Figure 1.




**Independent Variables** **Dependent Variable**

## 3.1 Research Design

According to Kothari (2004) research design is a plan, a road map and blue print strategy of investigations conceived so as to obtain answers to research questions. It is a procedural plan that is adopted by the researcher to answer research questions objectively, accurately and economically (Kumar, 1996). Research designs can be broadly classified into quantitative and qualitative research designs. This research study adopted descriptive research design since the researcher was interested in describing the case under study. This study used descriptive methods research approach which involveda desktop review of both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks (Muleya *et. al.,* 2020). The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone. Thus, the research study employed the mixed methods approach to attain research objectives.

### 3.2 Pavement condition surface judgement

| Judgement of surface | Value | Maintenance strategy |
|---|---|---|
| Excellent | 7 | Routine/PBC |
| Good | 5 | Routine/Periodic |
| Fair | 3 | Periodic/PBC |
| Poor | 1 | reconstruction |

### 3.3 Pavement Performance and Prediction

Pavement performance data usually include structural and surface characteristics, such as roughness and texture. In addition, some type of condition index indicating overall condition of pavement (e.g., pavement condition index [PCI] or condition rating system [CRS]) can be collected specific to the pavement type in the scope of LCA performed. A detailed review of pavement condition performance guidelines is discussed by Wolters and Zimmerman (2010) and by Pierce, McGovern, and Zimmerman (2013). Specific guidance on the type of performance inventory data should be collected; recommended approaches are provided in AASHTO's pavement management guide (AASHTO 2012).

The performance data should include progression models for predicting pavement future condition utilizing historical traffic and environmental regional data. Even though agencies have been collecting field performance data, prediction models may not be available. In the case that models are unavailable, historical performance information will need to be collected to build such models for the pavement type studied. When the field performance data do not exist or are not considered sufficient, existing models can be extended using the available information in the literature to ensure reasonableness. For example, pavement management programs for most state and local highway agencies use one type of overall pavement condition index (PCI) and IRI. Macro texture is less frequently collected, but may become increasingly available with the increased use of automated pavement data-collection vehicles.

An alternative to the use of PMS data to develop performance models is the use of calibrated mechanistic-empirical (ME) models. ME models must be used when the pavement structure, material or treatment being considered has not been built in the past, or when other variables such as traffic loadings (change of vehicle, tire or other technology) and climate are not well represented in historical data and hence have limited (if any) field performance data available.

Depending on the agency's practices, if such a planned schedule for the sequence of maintenance and rehabilitation activities does not exist, one should be established using the prediction models and trigger values. In addition to that application, performance models can be used to ensure equivalency of the two pavement types if a comparative LCA is conducted. Moreover, functional performance models (roughness and texture) provide input for the use-stage fuel-consumption analysis. Finally, when a network level LCA is conducted, pavement performance models provide an indication of the overall network health in terms of average remaining service life or average roughness levels.

Structural evaluation data providing structural stiffness and material strength properties can be incorporated in the use-stage calculations in relating structural response to rolling resistance. Back calculated modulus data or deflection basins obtained from the pavement deflection testing (using falling weight deflectometers [FWD] or rolling weight deflectometers [RWD]) can be utilized in evaluating rolling resistance due to structural response. [It is noted that back calculation procedures for asphalt-surfaced pavements for determining rolling resistance must provide viscoelastic properties, which requires time histories of deflection (rather than the standard practice of only collecting peak deflections) and the use viscoelastic back calculation procedures (in lieu of standard elastic back calculation methodologies)].

Representative site-specific field-measurement inventory should be used in developing an inventory for project-level assessment, whereas network-level averages for the same family of pavement structure can be used for network-level applications. Other field data are often required to determine thicknesses and material properties needed for the determination of structural response.

**3.4 Performance measures required and their uses in various pavement LCA applications**

| Performance Parameter | Use in LCA |
|---|---|
| Overall condition index (e.g., PCI, CRS) or Other Performance Measures (e.g., cracking, faulting, rutting) | • Predict service life of a pavement to establish equivalency for comparative LCAs. Determine an analysis period covering a specific segment of predicted service life.<br>• Design of maintenance and rehabilitation schedule when overall condition index is used as trigger. |
| Roughness (IRI) | • Provide input to the use stage to calculate pavement-related rolling resistance.<br>• Design of maintenance and rehabilitation schedule when IRI is used as trigger. |
| Macro texture (MPD) | • Provide input to the use stage to calculate pavement-related rolling resistance.<br>• Design of maintenance and rehabilitation schedule when friction is used as trigger. |
| Structural response-related parameter (e.g., surface deflection basin) | • Provide input to the use stage to calculate pavement-related rolling resistance. Inputs can include parameters to perform structural analysis and convert relevant pavement responses to excess fuel consumption. |

**3.5 Pavement Maintenance and Rehabilitation Schedule**

The data collection for future activities should include documentation of all of minor and major scheduled activities anticipated for the maintenance and rehabilitation stage of the pavement LCA. The data should include the type of activity (e.g., sealing, routing, patching, overlay, slab replacement, reconstruction, etc.) and the frequency or timing of each activity, as summarized in table 4-4. If a scheduled set of activities does not exist for the pavement studied, then an anticipated schedule of activities should be developed using the performance prediction models and historical activities for similar pavements representative of the project site conditions. The progression models discussed in the previous section can be used to develop a maintenance schedule. Those highway agencies that perform life-cycle cost analysis comparisons for alternative new pavement and rehabilitation projects will often have M&R schedules. Examples of planned activity schedules are provided in the discussion section.

**3.6 Maintenance and rehabilitation parameters collected for each activity**

| Maintenance Parameter | Unit (Expressed per Functional Unit) |
|---|---|
| Maintenance Process | Description or source when description can be found |
| Maintenance Cycle | Number per analysis period |
| Unit | Length, area, or volume expressed as a percentage of the affected pavement element |
| Processes Included | Transportation, materials consumed, construction activities |

Once the maintenance schedule is developed, the inventory database used for the materials and construction stages is generally used for this stage. Some pavement LCAs use actual applied activities based on work and change orders for historic activities.
The steps followed to develop inventory input and output flows for the construction stage should be repeated for each maintenance and rehabilitation activity.

**3.7 Attainment of Research Objectives**

**3.7.1 Establishing the Extent of Impact of road maintenance strategies on Performance of Road Projects.**

The extent of impact of the various identified factors influencing the performance of road construction projects will be categorized using the identified performance indicators outlined in the conceptual framework of this study.

**3.7.2 Establishing the Relationship between the maintenance strategies and the Road Performance**

The degree of agreement between respondents regarding the factors influencing the performance of road construction projects in Africa will be evaluated based on the internationally accepted performance indicators.

**4.1 Findings of the Study**

PCI method is a valuable tool for evaluating road pavement condition; it provides a systematic and rational basis for determining maintenance and repair needs and priorities. It is used to establish the rate of pavement deterioration and early identification of major rehabilitation needs to reduce or defer costly, time-consuming rehabilitation and reconstruction projects (Giuseppe Loprencipe, Antonio Pantuso and Paola Di Mascio 2017).

| | Level of severity | | |
|---|---|---|---|
| | Low | medium | High |
| Maintenance strategy | Routine/PBC | Periodic/PBC | Emergency/PBC |

In the Assessment on the Performance of Pavement Structure Due to Subsurface Course Materials, Ashebir B. et al in their study in 2020, concluded that the pavement condition survey on the road section from Assosa to Mendi required maintenance and based on this, possible maintenance option had been recommended for pavement distress with respect to level of severity on the pavement condition of the study area in order to sustain the design life and quality of the Pavement. This research finding emphasizes on the need for timely and appropriate maintenance strategy on road quality performance.

In a publication by ADB on Routine maintenance, the study established that the more deteriorated theroad the more intensive and thus costly the required repairs will be. While the road is still in fair condition, corrective maintenance may simply entail patching potholes, reforming the road surface, and undertaking minor repairs to the drainage system and road structures. If the road has already deteriorated to a poor condition, corrective maintenance will include complete resurfacing of large stretches of road, replacement or reconstruction of the drainage system and road structures, and possible reconstruction of the road base. Depending on the type of activities required, such maintenance is generally referred to as periodic maintenance (medium maintenance) or rehabilitation (major maintenance). The distance from the black line, indicating the road condition, to the desired good or very good condition indicates the level of corrective maintenance required, and thus the cost of such maintenance. After restoring a road to good condition, the deterioration process starts a new; hence, corrective maintenance needs to be done repeatedly. Although corrective maintenance, carried out when the road is still in fair condition, will have to be repeated more frequently than when this is only done once the road is already in poor condition, this results in lower overall maintenance costs and better overall road condition.

### 4.1.1 Routine Maintenance and Road Performance

The study established that road failures begin gradually with surface distress, cracking on shoulders, blocking of drains among others. If these are not notice early enough during routine checking and pavement condition analysis, then this will develop into more costly and result in pavement failure. A strategy for routine maintenance should ensure that staff are well trained and the use of right equipment to achieve optimum results Routine inspection is necessary to provide current and useful evaluation data. Periodic pavement maintenance practices should be employed to reduce aging of pavement failure. They further proved that effective maintenance can extend a pavement's life. Crack sealing and surface treatments can reduce in aging of asphalt pavement consequently improving its performance

### 4.1.2 Performance based contract maintenance and road performance

Most considered countries considered in this study use contractors for road maintenance where laws on public procurement process are followed. Public procurement is a major activity of government that consumes financial resources targeted at improving public financial management (Economic policy of Kenya, 2007), however according to Miles (2015), procurement is a complex process. In the process a lot of time is taken before the contractor moves to the ground to start road repair, consequently the performance of the road is reduced from the time the failure is noticed to the time action is taken. PBC therefore enhances road performance by ensuring that a contractor is always on sight to attend to any pavement failure.

Henry Kipkurui Muta1, Dr. Fredrick Aila, (2018) on their study on effect of performance based contracting on performance of road agencies in Kenya, the regression analysis results showed R- squared of 0.832 indicating a positive strong relationship between performance based contracting and road agencies performance**.**

According to (A. D. Mulmi, 2016) in his assessment of Performance Based Road Maintenance Practices in Nepal the Priority Investment Plan (PIP) showed that Nepal is losing the value of $1 billion due to the lack of proper maintenance works. Overall maintenance expenditure estimated by PIP (From 2007 to 2016) is Rs31.2 billion, representing twenty eight (28) percent of the total that includes upgrading and the new construction. Mulmi, further states that the possible benefits for the implementation of the of PBMC mentioned are savings of cost for road maintenance works, risk sharing and assurance of quality by the contractor introduction of innovation, increasing the efficiency of the road authority and contractors, reducing the administrative burden, user satisfaction, achieving a sustainable road management system, increasing the flexibility of work, and increasing transparency and reducing the chance of corruption.

### 4.1.3 Periodic maintenance and road performance

Periodic pavement maintenance practices should be employed to reduce aging and pavement failure (Ashebir B, 2020). Planned periodic maintenance is useful in averting any road failures before they occur or observed. Since many failures begins from the base due other factors like type of soil, stability of the base among others, periodic is useful in ensuring that the road pavement remains in its good condition.

Joloba (2014), effectiveness of applied periodic maintenance intervention in management of road performance, A case of Wakiso District, Uganda. This study investigated the effectiveness of applied road periodic maintenance in management of road performance with emphasis on Wakiso district. The major objectives involved studying the road infrastructure performance, evaluating effectiveness of applied routine maintenance intervention and development of a strategy for maintenance implementation. Local governments in Uganda receive funds from Central Government through Uganda Road Fund for road maintenance. The principle purpose of maintaining roads is to provide continuous acceptable conditions for undisrupted, safe and economic travel. Roads are expensive to construct, therefore well planned and timely maintenance interventions are required. Absence of current road condition assessment data and unreliable road maintenance equipment has contributed to ineffective routine road maintenance in the district. An improved strategy for routine maintenance has been developed whereby for effective routine road maintenance to be achieved, training for both staff and labour gangs should be emphasized every three years for a sustainable skills development and hence better outputs. In addition to that, selection of roads for routine maintenance should be based on vehicles per day and road condition for a particular road. When this is adhered to, value for money for routine road maintenance shall be achieved and hence better management of road performance.

A study by Audrius V. et al (2016) on improvement of road pavement maintenance models and technologies found out thatpavement condition evaluation by indicating present performance indicators level should be done timely and accurately at road level and whole network level. Ongoing support of pavement condition under network level, with a long-term strategy, allows prolonging the life of the pavement, improving traffic safety and meeting public expectations. This study confirms that road maintenance strategy improves the quality performance levels of road pavement. The study further established that Service-Based Model is based on Performance Indicators: reliability, availability, continuity, traffic safety, security, health, environment, economy, and politics.

Pavement Distress Index (PDI), used in many countries, is assigned to condition-based parameters as well as Distress Manifestation Index (DMI) (Chan *et al.* 2014; Kazmierowski, Ninguan 2002). The service-based is assigned to the most widely used Present Serviceability Index (PSI), Ride Comfort Index (RCI) (Chan *et al.* 2014; Kazmierowski, Ninguan 2002). Determining the pavement PSI, the main indicator is the surface roughness. In this study it was established that the state of the road network management and maintenance practices in different countries, it may be noted that systems, models and procedures differ for its complexity of the specific applications by the country. However, in the general point of view, the objective is the same to ensure long-term, cost-effective, social and environmental needs of the satisfactory operation of the road network resulting in improved quality of performance. The European and North American experience shows that using a pavement management system and the application of effective models, an average savings are from 15% to 30% of maintenance budget. Pavement deterioration prediction and condition monitoring is an indispensable factor for effective road asset management

This study went further to state that Superficial and Structural Condition show that the most deteriorated road section is the descending one. This one presents bad conditions in 28.1% of its route being more critical in the mountainous area where there are steep slopes and curves; and in the first kilometers of this route that are considered part of the urban area. On the other hand, 70% of the ascending road section has good conditions.

The first strategy was with slurry seal, which consists of applying a homogeneous liquid mixture of water, asphalt emulsion, mineral filler and well-graduated aggregate. The second strategy was with 40 mm over folder works, which consists of the application of a tack coat and the placement of a dense granulometry layer. The third strategy was milling and re-construction, which refers to the removal of 100 mm of existing asphalt layer and placement of 50 mm of a new layer.

**4.1.4 Emergency maintenance and road performance**

Due to the fact that natural disasters can occur in very complicated and unpredictable ways, simple static models no longer meet the needs of the road emergency. Consequently, the establishment of a road emergency response system should be based on an assessment of dynamic risks and stability, with a priority put on the five aspects (emergency teams, emergency equipment, emergency supplies, the contingency plan and emergency fund) and three dimensions (reduction, readiness and response) so that the developed system can adapt effectively to changing emergency situations to ensure timely and effective response for pavement performance (Zihan Zeng, 2016). Since disasters may not be easily predicted, planning for emergency response and strategy is key to improved road performance.

**4.1.5 Government regulation and funding of road infrastructure**

Countries with higher percentage of road funding like Botswana, Egypt, Rwanda, Kenya, Mauritius, among others had better roads than those with least funding like DRC, Siera Leone, Chad, Burundi among others (World Bank 2014). In their study Marco M A(2019) on Sustainable Road Maintenance Planning in Developing Countries Based on Pavement Management Systems with the objective of developing a useful procedure that allows the collection, analysis, processing and updating of pavement conditions data, with the vision of generating inputs for the implementation of sustainable strategies for maintenance and rehabilitation of roads, based on pavement management systems. This study concluded that pavement maintenance planning contributes to the improvement of highway performance, since it allows planning and administering the allocation of resources in making appropriate maintenance strategy decisions besides giving value for money on investments. This study established that there is a direct relationship between government regulation, funding and road performance

## II. Conclusions and Recommendations

Evaluating surface and structural conditions of the existing pavement is essential, in order to determine the maintenance intervention that provide greater benefits to road quality performance. The measurement of road performance, respect to maintenance strategies, represents an important chapter in road management process. In this field, several road performance indices related to road infrastructure needs to be defined to include but not limited to road condition evaluation, environment, and safety among others.

Once current road conditions have been gathered, it is possible to calculate the foreseeable life of both the pavement layer and structure in order to ensure that all the proposed maintenance works are carried out within the necessary time. For the contemplated cycle in the intervention plan, it is not necessary to carry out total pavement reconstruction works, so that the intervention proposals include surficial works only. However, this analysis allows the identification of the most damaged areas in need of total pavement maintenance works in future intervention plans. (Cafiso S.2016)

In general, results of the serviceability analysis show that pavement maintenance interventions carried out improved road pavement performance resulting in comfort and safety of users, according to the PSI. Additionally, some road sections already maintained favorable service levels, so the interventions helped preserve these conditions.

According to the literature review, the concept of road performance and sustainability can be applied at all stages of the pavement cycle. However, this proposal focuses on two stages. First, is the maintenance stage, through the improvement in the allocation of resources in M&R activities. Second, is the operation phase, through the improvement in the use of the pavement and its interaction with the user. Although the road condition prediction models allow an overview of the pavement conditions, it is necessary to obtain updated data in order to optimize the prediction models.

It is the conclusion of this research study that the proposed maintenance strategy contributes to the improvement of road quality performance, since it allows planning and administering the timely allocation of resources in making appropriate maintenance and rehabilitation decisions. Additionally, it allows generating valuable inputs for PMS implementation. The foregoing allows road management agencies in developing countries to provide a quality road infrastructure system to users. Therefore, effective maintenance strategy can extend a pavement's life since crack sealing and surface treatments can reduce in aging of asphalt pavement.

### *4.2* Recommendations

The influence of other factors such as poor drainage courses, level of groundwater table, variation of geologic materials along the road route and poor construction materials should be thoroughly addressed before beginning rehabilitation the road section in the future.

Detail investigation should be carried out on project areas; also the properties of material and method of construction should be done according to the design specification of project in order to serve the design period of a project in order to avoid the pavement failure. Adequate longitudinal drainage, cross drainages and other drainage facilities should be provided in order to control the drainage problem. Seal coats shall be applied to prevent infiltration of water through cracked surfaces.

For future research, it is recommended that detailed in-depth investigation should be carried out on related project; compliance with quality of materials and construction methods in accordance with ERA Standard Specifications in order to avoid future failure.

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